Report on sedimentology cores from Lower Passaic River, RM 10.9

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Summary
The objective of this study is to understand the nature of the sediments within the RM 10.9 deposit and its depositional history. Eleven cores were collected between October 18 and November 2, 2011, in the 'silt area' on the point bar / inner bend at River Mile 10.9 of the Lower Passaic River, New Jersey. The cores were collected using a vibrocorer and were drilled one foot into the 'native' sediments, which are red-colored, stiff, clayey silts and (very) fine-grained sands with gravel and stones, deposited during the last ice age. On top of this glacial till, a sequence of (gravelly) sand and mud is found. The sands are predominantly angular, poorly sorted and fine- to very coarse-grained. The muds usually are silty to (very) fine sandy and are rich in organic remains. In the point bar, the sediment sequence consist of thick layers of (gravelly) sand overlain by muddy deposits or muddy deposits directly on top of the glacial till. The channel bed consists of thick layers of sand. The muddy deposits consist of mixtures of clay, silt and very fine sand. The mixed state of the mud is not conclusive in discriminating between depositional conditions. The abundance of wood and organic debris indicate deposition under alluvial conditions. The origin of the suspended sediment can not be determined from the deposits.

References
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Version	Date	Author	Initials	Review	Initials	Approval	Initials
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1 Introduction

This report describes the results of inspection of sediment cores from the ‘silt area’ at RM 10.9 of the Lower Passaic River by Dr. Ad van der Spek (AvdS), senior coastal geologist at Deltares. These activities are carried out under the sub-contractor agreement between Moffatt & Nichol and Deltares for the Lower Passaic River Restoration Project (project reference 6664).

The cores were inspected between November 1, 2011 and November 4, 2011, at the Cooperating Parties Group (CPG) Facility, 1 Madison Street, East Rutherford, New Jersey.

The time schedule was as follows:

Oct. 31:	traveling from Amsterdam to Newark and East Rutherford, NJ;
Nov. 1:	meeting with Marcia Greenblatt (Integral Consulting Inc.) discussing the project and study questions and goals; introduction to risk assessment and safety procedures and tour around the facility by Kris van Naerssen (AECOM); start core processing (by Ellen Fyock, AECOM) and core description (AvdS);
Nov. 2-4:	core processing and description continued;
Nov. 3:	meeting with Maura Surprenant (AECOM), discussing the progress of the work;
Nov. 5:	no activities;
Nov. 6:	field visit to RM 10.9 during Low Tide; traveling to Amsterdam;
Nov. 7:	arrival in Amsterdam.

2 Objectives

The objective of this study is to understand the nature of the sediments within the RM 10.9 deposit and their depositional history. The aim is to provide insight on spatial variability and stratigraphy of the sediments within the sediment deposit. This information will be used together with other lines of evidence to characterize of the stability and transport patterns of these sediments.

3 Methods

3.1 Core collection

Eleven cores were collected between October 18 and November 2, 2011, in the ‘silt area’ on the point bar / inner bend at River Mile 10.9 of the Lower Passaic River, New Jersey, approximately between River Miles 10.6 and 11.1. See Figs. 1 & 2 and Table 1 for location of the cores. The locations were selected to cover the range of depositional/erosional patterns within the study area inferred from geomorphic conditions and bathymetric depth differencing. Six cores are situated in the ‘point bar’, the shallow, partly intertidal area in the inner bend of the river. One core (0331) is in the ‘nearshore’, one (0303) is in the ‘center channel’ and one (0336) is in the ‘bend channel’. Two cores are located on the boundary between 2 units: 0316 (‘point bar’ and ‘nearshore’) and 0349 (‘bend channel’ and ‘point bar’).

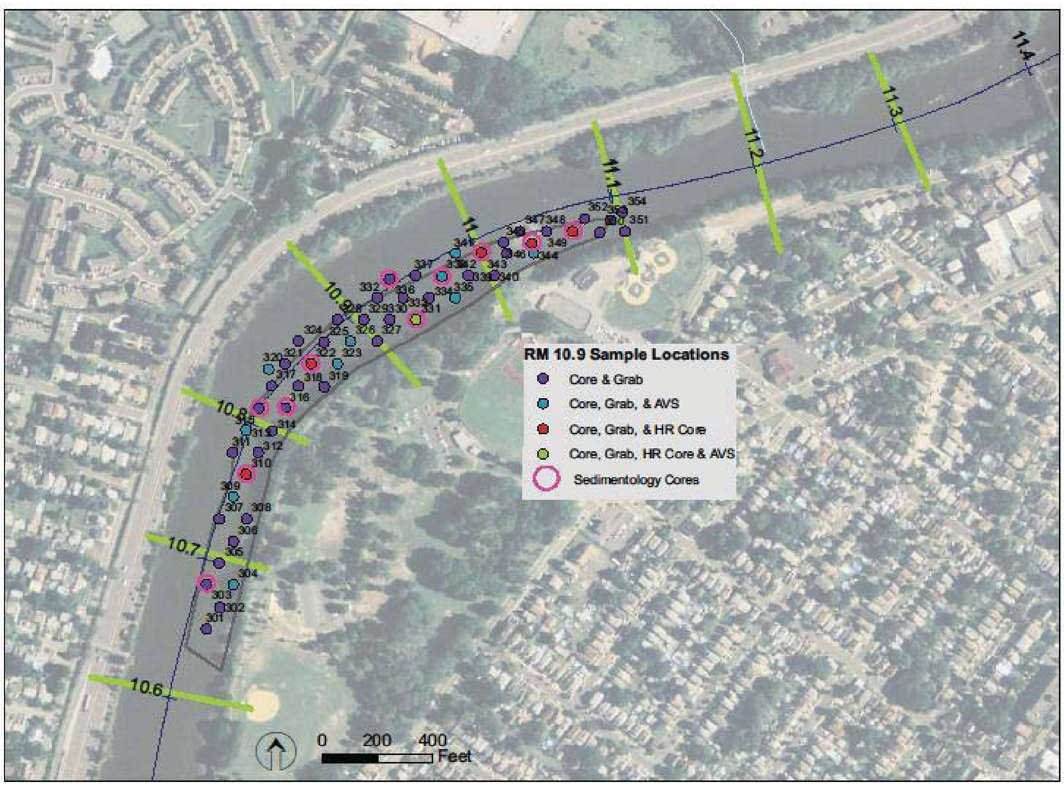

Fig. 1; location of the sedimentology cores collected at RM 10.9.

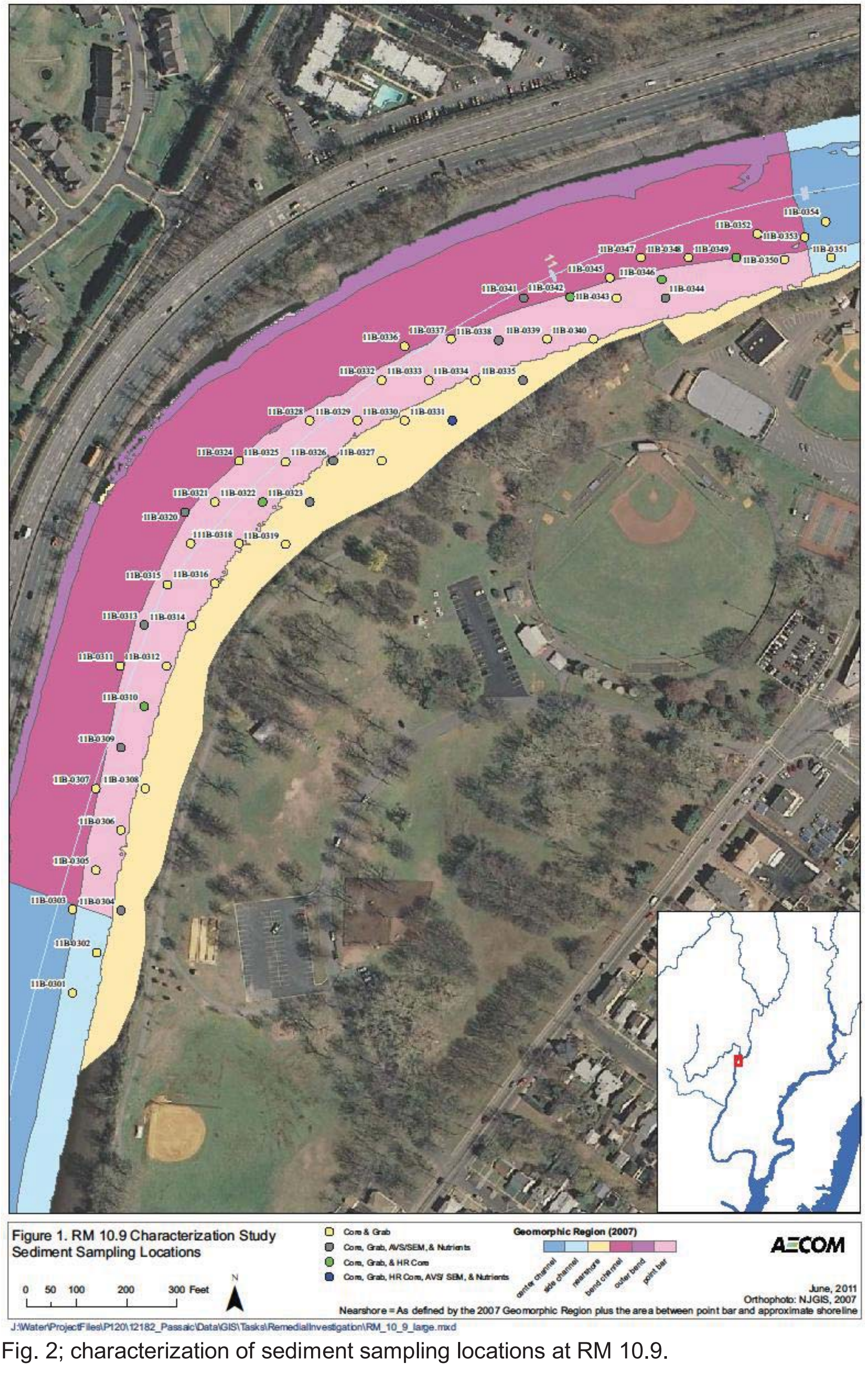

Fig. 2; characterization of sediment sampling locations at RM 10.9.

Table 1; locations of the sedimentology cores. Please note that water depths have not been corrected for tide levels. Bed elevations were derived from water depth after correction for water elevations (based on tide gages at River Miles 8.53 and 1.42). Data received from Maura Surprenant, AECOM, and Marcia Greenblatt, Integral Consulting Inc.

Station sampled	Sample Date	Water Depth (ft)	x-coord (ft)	y-coord (ft)	Bed Elevation NGVD29 (ft)	River Mile (see Fig. 1)	Geo-morphic Region (see Fig. 2)
11B-0342	2011-10-18	11.9	593440.55	723416.52	-9.7	11.00	point bar
11B-0336	2011-10-19	12.1	593120.15	723309.07	-8.7	10.94	bend channel
11B-0303	2011-10-20	12.5	592444.30	722194.96	-11.3	10.68	center channel
11B-0338	2011-10-24	10.1	593297.67	723334.10	-6.1	10.97	point bar
11B-0315	2011-10-24	7.6	592631.49	722850.05	-8.7	10.81	point bar
11B-0310	2011-10-25	10.9	592592.40	722600.38	-5.9	10.77	point bar
11B-0322	2011-10-27	7.0	592825.75	723006.72	-5.0	10.86	point bar
11B-0349	2011-11-02	11.1	593770.81	723500.56	-10.7	11.07	bend channel / point bar
11B-0346	2011-11-02	12.9	593621.30	723454.44	-8.8	11.04	point bar
11B-0331	2011-11-02	5.0	593205.92	723172.52	-0.6	10.94	nearshore
11B-0316	2011-11-02	7.7	592731.36	722853.60	-3.3	10.82	point bar / near shore

The cores were collected using a vibrocorer. The handling of the vibrocorer is described in Standard Operating Procedure SOP LPR-S-03 ‘Sediment Coring Using a Vibrocorer’. The cores were drilled one foot into the ‘native’ sediments, which consist of red-colored, stiff, clayey silts and (very) fine-grained sands with gravel and stones.

3.2 Core handling

The cores underwent the following procedure:

a. <u>Core handling on board</u>: dewatering of the top of the core, cutting the core in four-foot sections, storing the sections upright, all according to SOP LPR-S-03.

   Note that the core sections were drained by punching holes in the bottom cap and letting the excess pore water flow out during 15 minutes. This procedure was added at the request of AvdS and was discussed with AECOM staff (Maura Surprenant, Kris van Naerssen and Colin Plank) by conference call on October 14, 2011. A description of this additional procedure is given in Appendix 1.

b. Transporting the core sections from the sampling site to the Field Facility by boat and from the dock to the facility by car. The sections were transported in an upright position.

c. Core handling at the Facility: upon arrival, the cores were stored vertically in a cooling container. Some of the cores have been stored for up to 14 days[1]; see Table 2 for the interval between collection and description. Prior to description, the core sections were processed in the following way: cutting of the liner, followed by separating the sediment body in the core using spatula; checking the sediment for toxic vapors; when the vapor concentration level is below threshold value, the cores can be released for further handling, including photography of cores, per one-foot interval (photos available on CD, not included in this report), all according to SOP LPR-S-04 'Core Processing'.

Table 2; Sedimentology cores LPR RM 10.9

core nr.	*core ID*	*section*	*sec. length*	*collected*	*time*	*field picture ID*	*water depth*	*described*	*time*	*interval*	*bottom elevation*	*comments*
			(feet)				*(feet)*			*(days)*	*NGDV29 in ft*	
303	11B-0303-C2	AB	4	Oct 20, 2011	13:51	G111020-0000	12.5	Nov 1, 2011	16:50	12	-11.43	
	11B-0303-C2	BC	1.5	Oct 20, 2011	13:52	G111020-0001		Nov 1, 2011	17:40	12		
310	11B-0310-C4	AB	4	Oct 25, 2011			10.9	Nov 2, 2011	15:45	8	-5.67	
	11B-0310-C4	BC	4	Oct 25, 2011				Nov 2, 2011	16:45	8		
	11B-0310-C4	CD	4	Oct 25, 2011				Nov 2, 2011	17:25	8		
315	11B-0315-C3	AB	4	Oct 24, 2011	14:35	G111024-0003	7.6	Nov 2, 2011	10:55	9	-8.57	
	11B-0315-C3	BC	4	Oct 24, 2011	14:36	G111024-0004		Nov 2, 2011	12:15	9		
	11B-0315-C3	CD	4	Oct 24, 2011	14:37	G111024-0005		Nov 2, 2011	15:25	9		
316	11B-0316-C5	AB	4	Nov 2, 2011			7.7	Nov 4, 2011	14:15	2	-2.79	
	11B-0316-C5	BC	4	Nov 2, 2011				Nov 4, 2011	15:25	2		
	11B-0316-C5	CD	1.5	Nov 2, 2011				Nov 4, 2011	16:00	2		
322	11B-0322-C5	AB	4	Oct 27, 2011	15:58	G111027-0002	7.0	Nov 3, 2011	09:40	7	-5.42	

[1] *Fine-grained sediment will consolidate with time, increasing the strength of these sediments. Moreover, the bottom part of a core or core section will consolidate more due to the overburden of the overlying sediment. An extended period between sampling and description of a core could, in theory, cause additional variation in strength within and between cores.*

	11B-0322-C5	BC	4	Oct 27, 2011	15:58	G111027-0001		Nov 3, 2011	10:35	7		
	11B-0322-C5	CD	4	Oct 27, 2011	15:57	G111027-0000		Nov 3, 2011	11:30	7		
331	11B-0331-C5	AB	4	Nov 2, 2011			5.0	Nov 4, 2011	16:35	2	-0.61	
	11B-0331-C5	BC	4	Nov 2, 2011				Nov 4, 2011	17:47	2		
	11B-0331-C5	CD	4	Nov 2, 2011				Nov 4, 2011	18:05	2		
336	11B-0336-C6	AB	4	Oct 20, 2011	17:52	G111020-0002	12.1	Nov 1, 2011	11:40	12	-9.04	
	11B-0336-C6	BC	4	Oct 20, 2011	17:53	G111020-0003		Nov 1, 2011	13:35	12		
	11B-0336-C6	CD	2.6	Oct 20, 2011	17:55	G111020-0004		Nov 1, 2011	14:30	12		
338	11B-0338-C2	AB	4	Oct 24, 2011	10:51	G111024-0000	10.1	Nov 2, 2011	09:00	9	-6.33	
	11B-0338-C2	BC	4	Oct 24, 2011	10:52	G111024-0001		Nov 2, 2011	09:40	9		
	11B-0338-C2	CD	1	Oct 24, 2011	10:53	G111024-0002		???				missing !
342	11B-0342-C10	AB	4	Oct 18, 2011	17:41	G111018-0000	11.9	Nov 1, 2011	15:15	14	-9.63	
	11B-0342-C10	BC	3.6	Oct 18, 2011	17:42	G111018-0001		Nov 1, 2011	16:15	14		
						G111018-0002						
						G111018-0003						
346	11B-0346-C3	AB	4	Nov 2, 2011			12.9	Nov 4, 2011	11:10	2	-9.14	
	11B-0346-C3	BC	4	Nov 2, 2011				Nov 4, 2011	12:05	2		
349	11B-0349-C4	AB	4	Nov 2, 2011			11.1	Nov 3, 2011	14:55	1	-10.66	
	11B-0349-C4	BC	2.9	Nov 2, 2011				Nov 3, 2011	16:10	1		

3.3 Sedimentological description of cores

The sedimentological analysis of the cores comprised the following steps:

a. Macroscopic description of the following sedimentological characteristics:

- texture of the sediments (sand / silt / mud (clay), and mixtures of these components);
- estimate of the median grain size of the sand fraction using grain-size comparator[2] and hand lens; grain sizes are described according to the Wentworth classification (see Appendix 2 for reference);
- estimates of sorting of the grain sizes and the angularity of the sand grains;
- large components, such as wood, coal, stones, leaves, etc.;
- color of the (wet) sediment, using Munsell color codes[3]; and
- sedimentary structures.

These characteristics were recorded in core logs that are provided in Appendix 3.

b. The strength of the muddy deposits was tested using a *Geotester* pocket penetrometer[4]. In general, the strength of a mud will increase with time due to dewatering and consolidation processes. By measuring the strength at regular intervals, variation in strength, indicating variation in consolidation and hence, differences in age of a muddy deposit can be determined. Thus, a profile of the increase in strength with depth is produced, which can help to identify boundaries not visible with the eye. Please note that measured numbers have relative values only, since the penetrometer tip was not calibrated for soft muds. Mud and clay intervals that are overlain by thick sand layers were not tested. The results of these tests are presented in the core logs.

c. Sedimentologically relevant features have been photographed for documentation. Moreover, the complete cores were photographed. The compilated photos are shown in Appendix 4.

3.4 Field visit

To get an overview of the situation at RM 10.9, the sampling site was visited during Low Tide on Sunday November 6, 2011 (predicted Low Water: 12.56; visit from 13.30 to 14.00 hr). The site was accessed from the Riverside County Park (Riverside Avenue, Lyndhurst, NJ) which borders the ‘silt area’ between RM 10.6 and 11.0 (see Figs. 1, 2).

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[2] *Eijkelkamp brand; grain size fractions (in µm): 16-50 / 50-75 / 75-105 / 105-150 / 150-210 / 210-300 / 300-420 / 420-600 / 600-1000 / 1000-1400 / 1400-2000.*

[3] *Munsell Soil Color Charts, Year 2000 Revised Washable Edition, GretagMacbeth, New Windsor, NY.*

[4] *Geotester Pocket penetrometer, model 16-To161, serial nr. 07602172; used with a 25 mm diameter plunger.*

“Instruction for use: Place the … plunger against the sample and press with increasing strength, without sharp movements, until the plunger-tip has penetrated into the sample up to the notch. Maximum value is registered on the dial.” “The outer dial reads the penetration force in kg.” The strength is indicated in Kg (0.2 – 11).

Please note that the 25 mm tip used in this study was NOT designed for soft muds. However, the large cross-sectional area gives more differentiation in the readings than the smaller tips. However, the readings have NO physical meaning other than indicating the relative strength of fine-grained deposits.

4 Results

4.1 General description of sediments within silt deposit

The underlying 'native' sediments are red-colored, stiff, clayey silts and (very) fine-grained sands with gravel and stones. Cores 0316 and 0338 did not reach the 'native' sediments. Instead, they ended in, respectively, very dark-gray and brown stiff clays.

On top of the 'native' sediments, a sequence of (gravelly) sand and mud is found.

> *Please note that fine-grained sediments are described here as **mud**, which is a mixture of clay particles, organic matter, silt and/or very fine-grained sand and water. The term **silt** is reserved to describe the granular sediments with grain sizes ranging from 16 to 63 µm. This can potentially cause confusion, since sediments finer that 63 µm are sometimes described as silt, irrespective of their composition.*

The sands are predominantly angular, poorly sorted and fine- to very coarse-grained. Median grain sizes range between 150 and 2000 µm. The color of the sands is gray or brown. Brown sands are usually better sorted than gray sands. Layers of gravel are frequently intercalated in the sandy deposits, usually in relation with cross-bedding. However, dispersed gravel also occurs. The same holds for (pieces of) wood, other organic debris and clay balls. Fine sands can show low-angle cross-bedding and cross-lamination. Clay layers of millimeter to decimeter thickness, usually with a high organic content, occur in the sands. The thickness of sandy sequences ranges between 2 and 6 feet. Cores 0303, 0331 and 0336 contain thick sequences of sandy deposits.

The muds usually are silty to (very) fine sandy. They are low-angle cross-laminated to horizontally laminated with organic debris, but dispersed organic debris occurs as well. The muds are very dark brown to very dark gray to black in color. Sedimentary structures are usually not very clear, probably caused by the softness of the sediment. However, when visible, the muds show horizontal parallel lamination. Strength increases with depth and color can become lighter (see, e.g., core 0331). Occasionally, there are mm- to cm-thick layers of well-rounded and -sorted, (very) fine brown sand. The median grain size of these sands ranges between 75 and 300 µm. Mud deposits (including sand layers) can reach thicknesses of as much as 10 feet (core 0310). Cores 0322 and 0338 also contain thick mud deposits.

Frequently, the mud contains wood fragments (rootlets, twigs, branches) and occasionally layers containing packages of intact (tree) leaves are found. Moreover, artifacts such as pieces of aluminum, sheet plastic and other plastic objects, candy wrappers and pieces of coal are found in the mud. In one occasion (core 0316, at a depth of 3.4 ft) white shells, about 5 mm long (Ostracods?) were found.

The penetrometer tests show that muddy intervals, in general, increase in strength with depth. However, small-scale fluctuations can blur this picture. Larger deviations can occur near the tops and bottoms of core sections. In general, the muddy tops of cores show low strengths, but for cores that have been stored for more than 7 days (see Table 2 for intervals between collection and analysis of cores), higher strengths are found. Thus, it is not clear if the strengths measured at the top of the cores are representative of the situation in the field. The muddy top layers were possibly softened by the core collection and handling.

Mud strength was not measured in cores 0303 and 0336 since the tops of these cores consisted of thick sand layers.

The sediments in the individual cores are described below and are shown in core logs that can be found in Appendix 3.

4.2 Core summaries

The sediment in the cores will be described from bottom to top, following the chronological order of deposition. The codes given with the sediment colors refer to the Munsell Soil Color system.

- Core 0303

In core 0303, the ‘native’ sediment consists of dark reddish brown (Munsell color code 2.5YR 3/4), stiff, very fine- to fine-grained clayey sand with some very coarse gravel. This is a glacial deposit. On top of this lies about one foot of very dark gray to black, stiff silty to sandy clay that alternates with layers of well-sorted, very-fine clayey sand. In the bottom part wood and organic debris occur and pieces of hard, black coal (anthracite) are found at the top. On top of the clay comes a very dark gray (10YR 3/1), fine to medium sandy deposit that is over 3 feet thick. The lower part of this sand is relatively coarse and poorly sorted, the upper part is well-sorted and contains organic debris and leaves and roots. The middle part of the sand layer shows an alternation of coarser and finer layers, that includes clay balls and an occasional snail shell. At a depth of 1.88 feet plastic occurs in the sand. The sand is overlain by 0.25 feet of black (7.5YR 2.5/1) sandy clay, on top of which a layer of about 0.5 feet of dark reddish brown (5YR 3/2), rounded and moderately well-sorted medium-grained sand occurs. The color suggests that this is reworked ‘native’ glacial sediment.

- Core 0310

The ‘native’ sediment in core 0310 consists of dark reddish brown (2.5YR-3/4), very fine to fine sand. The top of the native sediment is disturbed; a lump of asphalt and plastic were pushed into the sediment during coring. The reddish brown sediment is overlain by over 7 feet of very dark brown (10YR-2/1,2) to very dark gray (10YR-3/1) to black (10YR 2/1) silty to sandy mud that is locally parallel or low-angle cross-laminated and contains layers of well-sorted fine sand that are up to 0.3 m thick. Moreover, layers of organic debris and dispersed plant remains and wood are found. Artifacts, such as plastic, a plastic bag (filled with mud), candy wrappers and pieces of aluminum, occur both in the mud and in the sand layers. The strength of the mud increases with depth. The upper 3 feet of the core consists of soft, black, silty to sandy mud that is both parallel and low-angle cross-laminated. The strength of the mud in this interval does not increase with depth. Organic debris occurs in layers and dispersed in the mud and layers of packed tree leaves are found (0-0.15 ft; 1.7-2.0 ft). A layer of well-sorted fine-grained sand occurs from 2.4 to 2.5 feet.

- Core 0315

The ‘native’ sediment in this core consists of dark reddish brown (2.5YR-3/4), consolidated and well-sorted silt to (very) fine sand with low-angle cross-laminated intervals, sometimes with intercalated thin clay layers (from 8.2 to 8.6 ft), and a cross-bedded interval with coarse gravel (from 9.5 to 10.0 ft). The river deposit starts with 1.4 feet of very dark gray (10YR-3/1), poorly sorted and angular medium to coarse (clayey) sand. The sand contains clay balls and gravel, the lower part is brownish in color. On top of this lies 2.5 feet of very dark brown

(10YR-2/2) to very dark grayish brown (10YR-3/2), moderately to well-sorted, fine to medium-grained sand with dispersed gravel and debris. The sand shows low-angle cross-lamination and cross-bedding and contains thin layers of organic debris and clay and intercalations of very dark gray (10YR-3/1), laminated (silty) clay that is rich in organic components (e.g. tree leaves). The top of the core consists of a very dark gray (10YR-3/1), locally parallel-laminated silty clay, that contains (thin) layers of organic debris and sand and dispersed plant remains. The lower 0.15 feet of this interval consists of parallel laminated organic debris and includes a plastic Christmas tree light. The strength of the clay is comparatively high but shows no clear correlation with depth. The upper part of this core interval contains two layers of fine sand and the top consists of a thin layer (0.1 ft) soft, black mud.

- Core 0316

Core 0316 does not reach into native sediments. The lowermost deposit is a very dark gray (10YR-3/1) stiff clay that contains layers of organic detritus. This is overlain by 3 feet of fine to medium sand with a messy appearance; pebbles, clay and mud balls, pieces of wood, lumps of organic material occur in the sand. The sand itself is moderately rounded and sorted and grayish in color. It shows some distorted low-angle cross-lamination and has an organic clay layer at the bottom. A six-foot thick layer of black to very dark gray (10YR-3-2/1) mud overlies the sand. The mud contains plant remains and thin (mm-thick) layers of organic debris and fine sand. The mud contains sandy intervals and organic debris occurs dispersed through the mud. Small, fragile white shells, probably of Ostracods, are found at 3.4 feet and pieces of anthracite occur in the lower part. The strength of the mud increases slightly with depth over the upper 4 feet and more or less constant between 4 and 6 feet. The upper 0.75 feet of the mud is soft, black in color and has a pebble and a sand ripple at the top. Organic debris occurs in layers and dispersed.

- Core 0322

Core 0322 contains a ‘native’ silty clay that shows color banding: reddish brown (2.5YR-4/4), alternating with weak red (10R-4/3), on top of a dark reddish brown (2.5YR-3/4) very fine sand. The lower part of this sand is finer and clayey, is reddish brown (2.56YR-4/3) in color and shows some color banding too. The color banding is possibly a reflection of original layering of the sediment. The top of the ‘native’ sediment is disturbed, probably due to coring. It is overlain by a foot of poorly sorted, greyish medium to coarse sand that shows cross-bedding with layers of fine to medium pebbles and some disturbance caused by coring. A 0.3 feet thick layer of very dark gray (10YR-3/1) silty mud with low-angle cross-lamination with organic debris bounding the lamination, and wood remains overlies the sand. On top of this comes 0.8 feet of very dark gray (10YR-3/1), well-sorted and rounded, medium to coarse sand that contains clay balls and organic debris. It shows cm-scale cross-bedding with organic debris bounding the cross-beds and the lower 0.2 feet consists of coarse, moderately rounded but badly sorted sand with medium to very coarse pebbles. This sand is overlain by 6 feet of soft mud that contains intervals of organic debris and plant remains, thin layers of well-sorted and -rounded sand and dispersed pebbles and organic debris. The color of the mud changes from black at the top to very dark gray (10YR-3/1). The mud contains packed tree leaves (6.15 to 6.30 ft), low-angle cross-lamination (from 5.9 to 6.5 ft) and pieces of aluminum (at 6.5 ft). The strength of the mud slowly increases with depth. The high value at 4 feet, the bottom of section AB, is likely due to consolidation during storage of the core. The upper 1.5 feet of the core consists of very soft, black silty mud that contains some small branches and pebbles.

- Core 0331

Native sediments in core 0331 consist of a dark reddish gray (2.5YR-4/2), stiff (silty) clay that changes upwards in color to reddish brown (2.5YR-5/3 to 4/3) and finally grades into reddish brown (2.5YR-4/4) silt. On top of this lies almost 6 feet of poorly sorted, angular, gray medium to coarse sand. The sand contains intervals with fine to coarse gravel, in thin layers on foresets of cross-bedding and dispersed, and intercalated gravel layers (5.1-5.3 ft; 6.65-6.85 ft). The lower 0.15 ft is reddish in color, the upper 0.07 ft is fine-grained. On top of the sand comes 0.5 feet of very dark gray (10YR-3/1) sandy clay that contains wood (a tree branch) and 0.4 feet of poorly sorted, fine to coarse sand with very coarse gravel in the lower part, that fines upwards. An interval of 0.85 feet of stiff mud (or clay?), very dark gray (10YR-3/1) to brown (10YR-4/3) to very dark greyish brown (10YR-3/2) in color and containing a layer of very fine to fine sand overlies this sand. This stiff clay is overlain by 0.05 feet thick black layer of organic debris and 0.4 feet of very dark gray (10YR-3/1) mud. The strength of the mud increases with depth. The mud is overlain by a thin (0.06 ft) layer of very fine to fine sand with 0.78 feet of soft black mud on top. This mud contains a pebble and a sand ripple at the top.

- Core 0336

Core 0336 starts with reddish brown (5YR-4/4) clayey silt with some low-angle cross-lamination and a dropstone at the base of the core. This silt is overlain by dark reddish brown (2.5YR-3/4) very fine to fine sand and reddish brown (5YR-4/4 to 2.5YR-4/4) silty clay to clayey silt. On top of these 'native' sediments comes 1.7 feet of black clay (10YR-2/1) with an organic-rich top, plant debris in layers, that grades upwards into pure organic debris and plant remains. This clay is laminated, its lower 0.8 ft is very rich in wood (stems, roots, twigs, leaves) and the bottom part consists of sandy clay. A 3 foot-thick sandy sequence of medium to coarse, dark brown-gray sand overlies this clay. The sand contains pebbles and wood fragments, sometimes in low-angle cross-beds, pine-tree needles and a big chunk of wood (root or branch?) at 4.04-4.07 feet. A 0.15 foot-thick layer of dark brown-gray sandy clay is intercalated in the sand and its top consists of organic-rich clayey sand with wood fragments and ripples. This sand is subsequently overlain by 0.1 feet of black organic clay with wood fragments, 0.3 feet of dark gray, slightly clayey, medium sand with wood fragments, 0.3 feet of dark gray, muddy silt grading downwards into black organic clay and rich in plant debris and 1.25 feet of medium gray, medium- to coarse-grained sand with gravel, wood fragments, pieces of anthracite and thin layers of organic debris that show some low-angle cross-bedding.

- Core 0338

Core 0338 consists of 8 feet of dark brown to black (10YR-2/1) silty clay and does not reach the native sediments. The clay contains some mm-thick, fine- to medium-grained sand layers, some dispersed plant remains and organic debris on the lamination. Below the sand layer at 5.5 feet, it is slightly lighter in color (very dark gray 10YR-3/1), the lower foot is brownish in color (dark brown 10YR-3/3 to very dark grayish brown 10YR-3/2). The top of the clay is very soft, its strength increases with depth. The lowest part of the core consists of stiff, dark brown (10YR-3/3) clayey silt.

- Core 0342

The native sediments in core 0342 consist of dark reddish brown (2.5YR-3/3,4) silty clay, grading upwards into clayey silt, with some color banding at the top. They are overlain by 0.25 feet of poorly sorted, medium-grained dark reddish brown (5YR-3/2) sand with some gravel, 0.8 feet of dark gray (5YR-4/1), poorly sorted medium to coarse sand with some fine gravel at the top and coarser gravel at the base, and 0.7 feet of dark reddish brown (5YR-3/2), fine to medium sand that is fining upwards in grain size and contains some pebbles at the base. Note that the red-colored sand is reworked native material. On top of the sand lies

3.4 feet of very dark brown gray (2.5Y-3/2), silty clay that contains very thin layers of well-sorted and rounded fine sand and a 0.1 ft thick layer of fine to medium sand, very dark gray (5YR-3/1) in color. The silty clay shows mm-scale lamination at the top. The strength of the clay is more or less constant over the interval but the bottom part shows to be significantly stiffer.

- Core 0346

A brown (7.5YR-4/2), poorly sorted, very fine-grained sand with a very stiff sandy clay on top forms the native sediment in core 0346. One-and-a-half feet of mud to clay of varying color (changing downwards from very dark gray/black 10YR-2-3/1, to very dark gray 10YR-3/1, to very dark grayish brown 10YR-3/2, to dark brown 10YR-3/3) overly the native sediment. This mud/clay contains some mm-thick, low-angle cross-laminated layers of coarse organic debris and very fine sand. On top of this come 2 feet of very dark gray (10YR-3/1) mud that contains thin layers of organic debris, alternating with sand layers of 0.1 ft and more thick. This sand is fine to medium-grained, low-angle cross-laminated, moderately sorted and rounded, and has some thin clay layers and layers of organic debris intercalated. The lower sand layers are well-sorted. Two feet of black mud with dispersed organic debris, thin layers of well-sorted, angular fine-grained sand and thin and thicker layers of organic debris come on top of this layer. The black mud shows some low-angle cross-lamination and contains scraps of aluminum (2.3, 2.5 ft). The strength of the black mud increases slightly with depth. The top of the core consists of 0.7 feet of very dark gray (10YR-3/1), very soft mud.

- Core 0349

Core 0349 reached down into a dusky red (2.5YR-3/2) to weak red (2.5YR-4/2) sandy clay, with gravel, in varying sizes, and stones. The gravel layers suggest some cross-bedding. The sandy clay grades downwards into reddish brown (2.5YR-4/3) silt with some very fine to medium sand, concentrated in spots. These native sediments gradually grade into very dark gray (10YR-3/1) to very dark grayish brown (10YR-3/2) mud to clay. This fine-grained deposit contains some wood and thin layers of organic debris and layers of up to 0.1 ft thick, well-sorted and -rounded, very fine to medium sand. Its top is slightly silty, its lowest part shows some color banding. Its strength gradually increases with depth. It is overlain by 0.4 feet of very dark gray to black, moderately sorted and rounded, medium to very coarse-grained sand with some gravel at its base and that fines upwards, with 1.55 feet of very soft, black mud on top. This mud contains some dispersed organic debris and some gravel. Its strength slightly increases with depth.

4.3 Field visit

During Low Tide the top of point bar was exposed. The supratidal part of the point bar consisted of sand with gravel and stones, the intertidal part was sandy, with washed-out ripples at the surface (Photo 1-3). This area was scattered with debris, such as gravel, boulders, timber, tree trunks, tree leaves, concrete lumps and slabs, plastic buckets, etc. Between RM 10.7 and 10.8, a distinct zonation in the intertidal zone was visible; a zone of sandy deposits in the high intertidal zone was bordered by a zone of sand with scattered organic debris on top in the lower intertidal zone (Photo 1). The latter zone suggests a more muddy composition, which is not the case, see Photo 3. However, deposits with a ‘sandy appearance’ sometimes proved to be muddy (Photo 4).

Photo 1: top of point bar near RM 10.7 during Low Tide, looking northwards/upstream. A distinct zonation parallel to the water line is visible, which is caused by organic debris deposited on the surface (compare photo 3).

Photo 2: washed-out ripples on the sandy intertidal part of the point bar near RM 10.9.

Photo 3: sandy point-bar deposits near the high-water line at RM 10.7. The sediment in the upper left corner of the photo is darker due to organic debris deposited on the sandy surface.

Photo 4: muddy sediments near the high water line at RM 10

5 Interpretation and discussion

5.1 The deposits of RM 10.9

The sediment in the cores can be divided in three categories (from top to bottom): (1) muddy river deposits, (2) sandy river deposits and (3) 'native sediments'.

Muddy river deposits

The muddy deposits consist of mixtures of clay, silt and very fine sand. In general, these mixtures can be formed either by simultaneous deposition of different grain-size fractions, or by post-depositional mixing of individual sediment layers of different composition by burrowing organisms. Since no traces of burrowing organisms have been found in the cores, post-depositional mixing is unlikely. This means that the mixed state of the mud is a characteristic of the conditions of sedimentation although it is also conceivable that the macroscopically 'mixed' appearance of the mud is the result of alternating very thin layers of clay and silts/very fine sands. Therefore, the mixed state does not help in discriminating between depositional conditions (such as, e.g., salinity). However, taking into account the abundant occurrence of wood and organic debris, deposition under alluvial conditions seems most likely, although this does not reveal what the source of the suspended sediments is. The origin of the sediment depends on the contributions of upstream migration associated with the tides and the turbidity maximum and downstream migration with freshwater. The relative contributions of these mechanisms cannot be discerned from the nature of the deposits alone. The fine-grained deposits were formed under low to moderate flow conditions.

The cores from the point bar show that mud deposition is the dominating process. The soft, black muds are 1.5 to 4 feet thick. The mud at the top of the cores is very soft, suggesting (geologically) recent sedimentation. However, disturbance of the natural state of the upper muddy layers during core collection with a vibrocorer and subsequent core handling (see section 4.1 and discussion in section 5.2) is possible. In cores 0331 and 0316 (located at the top of the point bar), sand ripples are found on top of the mud at the top of the core (together with gravel). The sand ripples suggest migration over the mud surface, the gravel appears to occur at the top of the point bar (see results from Field Visit).

Layers of sand occur intercalated in the muddy sequences. Thick sand layers that are in general fining upwards in grain size, were formed by transport and deposition of sand during high-energy events. After an event, normal conditions, *viz.* deposition of fine-grained material, would recur. The sand layers in the point bar are difficult to correlate. Intercalated (very) thin, fine-grained sand layers suggest smaller scale fluctuations in current velocities. The aluminum scraps and plastic that are found in the mud down to the lowest levels suggest that the mud deposits cannot be very old[5]. Recently received historical information shows that the Lower Passaic River between RM 8.3 and RM 15.4, including the point bar at RM 10.9, was dredged down to 10 feet below MLW in 1931/32 (Iannuzzi et al., 2002, in Table 1 in USACE, 2008). In the following years the dredged channel gradually filled in (see Fig. 3). This

[5] *Mass production of aluminum in the US started at the end of the 19th century (1886 to 1888); aluminum foil was first used in the United States in 1913 for wrapping Life Savers, candy bars and gum. The first plastics were produced in the nineteen-thirties (data from Wikipedia). Note that the results of age dating of the sediment collected during other studies for the LPR project, which were not made available to this author, should be reviewed and evaluated to obtain a more reliable estimate for the age of this deposit.*

information corroborates the age of the mud deposits and hence, the geologically recent deposition in the point bar at RM 10.9.

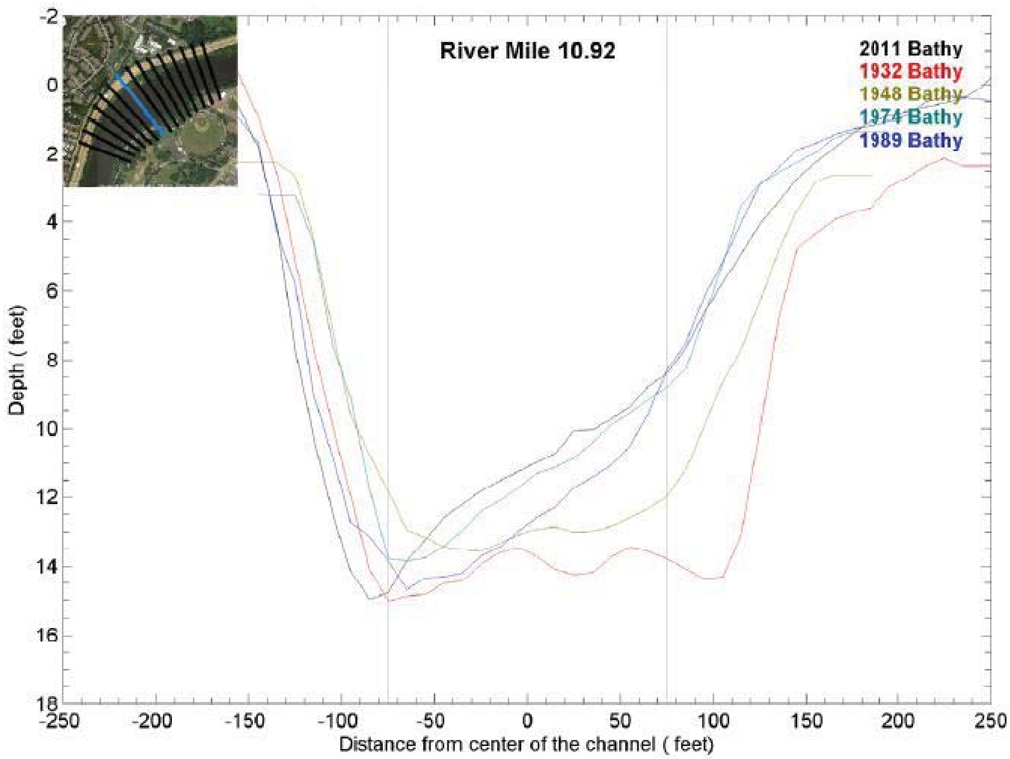

Fig. 3; cross-section through the river channel and point bar at RM 10.9, showing the dredged 1931/32 channel profile and the shallowing in the point bar over the following years. The shallowing indicates deposition of up to *c.* 8 feet of sediment over the period 1932-2011. (Data from USACE 1931, 1948, 1974 and 1989).

Sandy river deposits
The cross-bedded, relatively coarse-grained sands were transported by higher velocity currents, likely related to flood events. The angularity of the sand grains, the poor sorting of the sand and the high gravel content suggest that the source is glacial till (the 'native' sediment, see below), that was eroded and transported by the river. The occurrence of wood and organic debris confirm the alluvial conditions.

The cores that were collected from the river channel (cores 0303 and 0336; see Figs. 1,2) have sand at the top, indicating that the channel bed consists of sand and that currents in the channel are such that they do not allow fine-grained material to accumulate. Core 0315 from the toe of the point bar has a sandy top that is overlain by a thin mud layer (0.1 ft thick).

'Native' sediments
The 'native' sediments, which are red-colored, stiff, clayey silts and (very) fine-grained sands with gravel and stones, are glacial tills, laid down by glaciers and land ice during the last ice age. Almost the entire Passaic River Basin was subjected to glacial erosion and deposition

during the last stage of the Wisconsin glaciation, which began about 80,000 years ago and ended around 10,000 years ago (USGS, 2012). Considerable quantities of stratified sand, silt, gravel and clay were deposited in a glacial lake covering the area (Feasibility Study Work Plan, 1995; p. 2-1).

The top of the glacial till in the point bar area occurs at about the same level (with exception of core 0331), 15 to 16 feet below NGDV29. This is likely to be caused by the dredging in 1931/32.

5.2 Stability of the silt deposit at RM 10.9

Sequences of (gravelly) sands overlain by muds (cores 0315, 0316, 0322, 0331, 0342) indicate sand transport and deposition under a high-energy regime, followed by a drastic reduction in the energy leading to deposition of fine-grained material under low to moderate flow conditions.

The lower parts of the mud sequences are consolidated, which indicates little removal of sediment over time. The occurrence of sandy beds in predominantly muddy intervals (e.g., cores 0349, 0346, 0338, 0315, 0310) indicates occasional high-energy events in a generally low-energy environment. The deposition of sand is occasionally preceded by erosion of the mud.

All cores from the point bar and nearshore area have soft muds at their tops. These mud layers, with the exception of the one in core 0315, are too thick to be deposited recently. Moreover, the strength profiles do not indicate significant jumps in strength with increasing depth. This suggests that the post-Hurricane Irene flooding caused little erosion of the mud deposits. The softness of the muds, which suggests susceptibility to erosion, could have been caused by the vibrocoring.

In core 0315 which comes from the lower part of the point bar close to the channel, a 0.25 ft-thick layer of fine sand occurs under 0.1 ft of mud. This sand layer was deposited during a flood event, such as the post-Hurricane Irene flood in late August 2011. In the case of core 0349 there is a fining-upwards sand bed from 1.5 to 2 feet down, indicating a phase of erosion and sand transport. On top of this sand bed, 1.5 feet of soft mud is deposited. This sequence could be the result of the post-Hurricane Irene flood, but deposition of 1.5 feet of mud in 2 months time is not very likely. In any case, erosion does occur, as is witnessed by this sand layer. Moreover, bathymetric changes over the period July - October 2011, which includes the post-Irene flood, show erosion of the point bar. In the other cores sand layers are found at greater depths (see core logs in Appendix 3).

At the top of core 0303 from the main channel of the river, a reddish-brown medium sand layer occurs on top of black sand. This material resembles the sands found in the native deposits and is likely to be derived from either erosion of the glacial till or reworking of an older deposit. The sand was transported over the river bed to this location. This might be related to the recent flooding.

6 Conclusions

The river deposits at RM 10.9 rest on top of red-brown, stiff clayey silts and (very) fine-grained sands with gravel and stones. These are glacial tills, laid down by glaciers and land ice during the last ice age. The top of the native glacial till in the area occurs at about the same level, 15 to 16 feet below NGDV29, in the point bar and channel area, due to dredging in 1931/32. In the nearshore zone, this top is found shallower than 10 feet (see core 0331). The native till is overlain by sequences of sand and mud. In the point bar, there are thick layers of (gravelly) sand that are overlain by muddy deposits or muddy deposits directly on top of the glacial till. The river channel bed consists of thick layers of sand, with minor intercalations of clay. The sand layers in the point bar are difficult to correlate.

The alternation of sand and mud indicates transport and deposition of sand by strong currents, presumably during flood events, and deposition of fine-grained sediments and organic debris under low to moderate flow conditions. Low energy conditions prevail in the point bar, as can be concluded from the muddy tops of the cores from that area. Cores from the channel bed (0303, 0336) are predominantly sandy with only thin layers of clay and/or mud, indicating that here the flow regime is more energetic.

The thick, predominantly muddy sequence in the point bar at RM 10.9 was deposited following channel dredging in 1931/32.

The lower parts of the mud sequences are consolidated, which indicates little removal of sediment over time. The occurrence of sandy beds in predominantly muddy intervals indicates occasional high-energy events in a generally low-energy environment. The deposition of sand is occasionally preceded by erosion of the mud.

All cores from the point bar and nearshore area have soft muds at their tops. Why these muds are soft is not clear. Weakening of the muddy tops of the cores due to the vibrocoring is possible.

The muddy deposits consist of mixtures of clay, silt and very fine sand. The mixed state of the mud is not conclusive in discriminating between depositional conditions. The abundance of wood and organic debris suggests deposition under alluvial conditions, although this does not reveal what the source of the suspended sediments is. The fine-grained sediments deposited in the RM 10.9 area can be supplied both by upstream migration associated with the tides and the turbidity maximum and downstream migration with freshwater. The origins and the proportions from potential sources of the suspended sediment cannot be determined from the deposits based on the analyses conducted as part of this work.

7 References

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USACE Condition Survey – July 1948 –soundings digitized from a digital version of the chart after rectifying the chart to the navigation channel. (file 494)

USACE Condition Survey – May 1974 –soundings digitized from a digital version of the chart after rectifying the chart to the navigation channel. (file 693)

USACE Condition Survey – Nov 1989 –we received this survey in digital form, though it is also available in digital charts. (file 798)

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A Appendix 1

RM 10.9 Sedimentology Core Collection

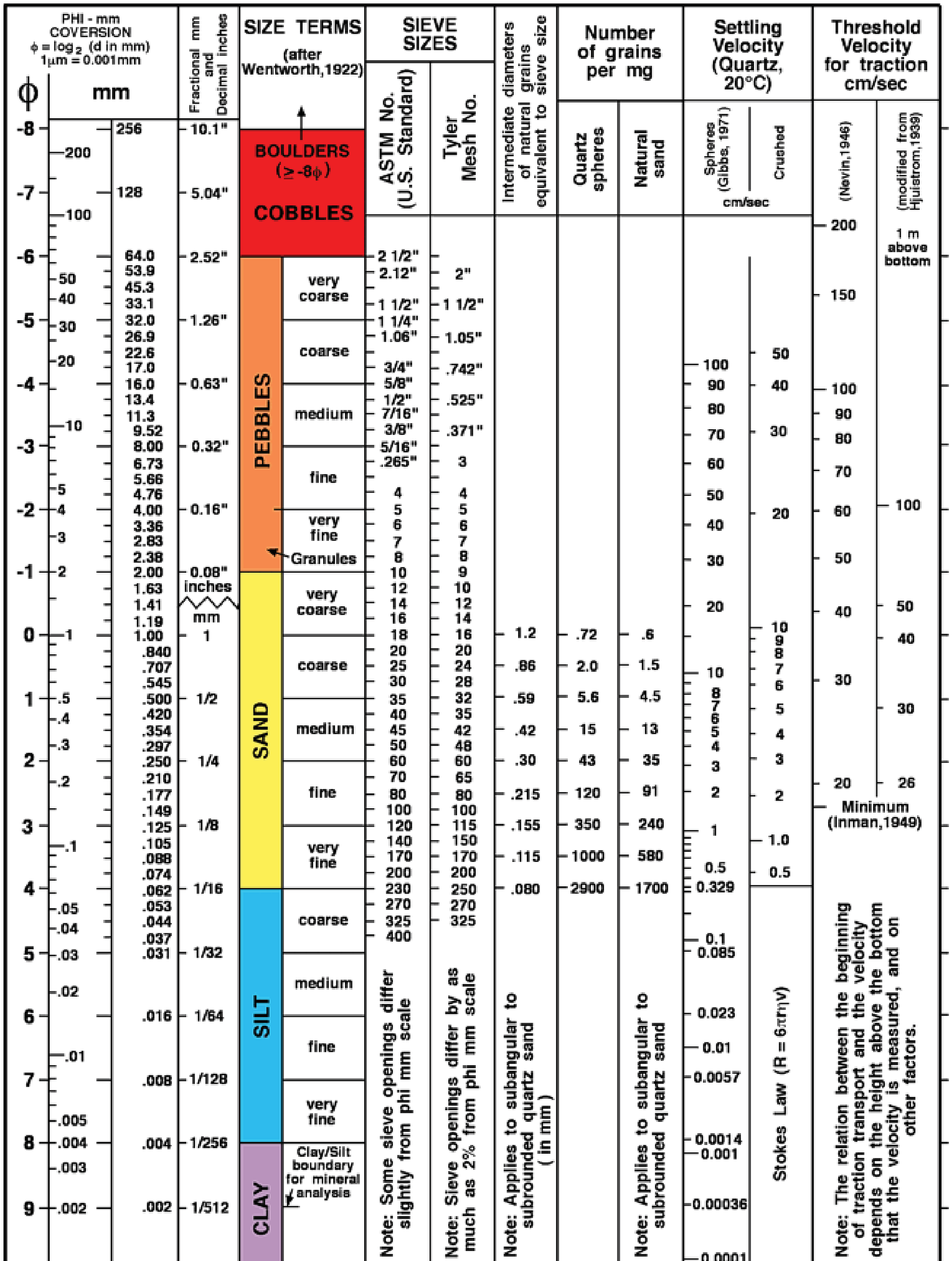
Procedures for collection of core samples outlined in LPR-S-03 will be implemented, with the following additions as per Ad van der Spek, Deltares:

Drainage procedure bottom end core sections

1. Core is cut in 4-feet sections
2. Photograph each core section and provide description in core log.
3. Check what kind of material is in bottom part of core section
    a. Soft sediment (that might flow out of the liner): cap bottom part of core immediately and tape cap to core liner
    b. Non-soft sediment:
        i. punch the bottom cap with an ice pick, an awl, or a similar tool (see figure); 3 punches, oriented in a triangle, will be enough; the punches will form small slits in the soft plastic cap that will allow the water to get out but will keep the sediment in

        ii. put the prepared cap on the lower end of the core section and tape it to the core liner
        iii. let the core section drain in an upright position for 10 to 15 minutes; most of the excess water should have come out by then. The core should be raised above the intermediate container to facilitate drainage.
        iv. Collect excess water during drainage into an intermediate container for disposal as outlined in SOP LPR-G-04 – Investigative Derived Waste (IDW) Handling and Disposal
        v. Cover the small slits with tape
        vi. Photograph each drained core section and provide description in core log. Note any disturbance in core appearance potentially related to drainage and/or any significant sediment load within the drained water.
4. Store the core sections in an upright position for transport and storage, as described in SOP LPR- S- 03.

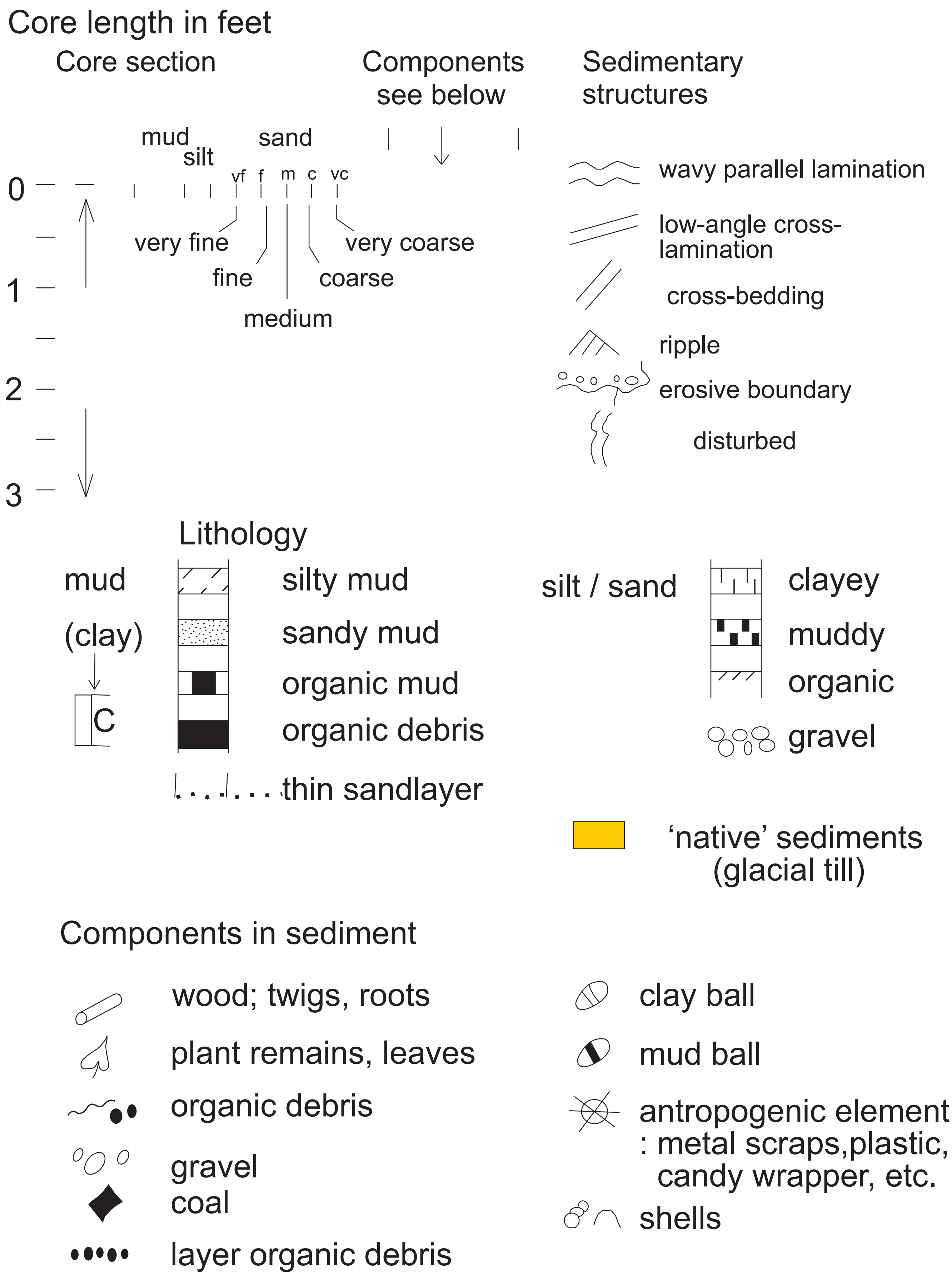
B Appendix 2

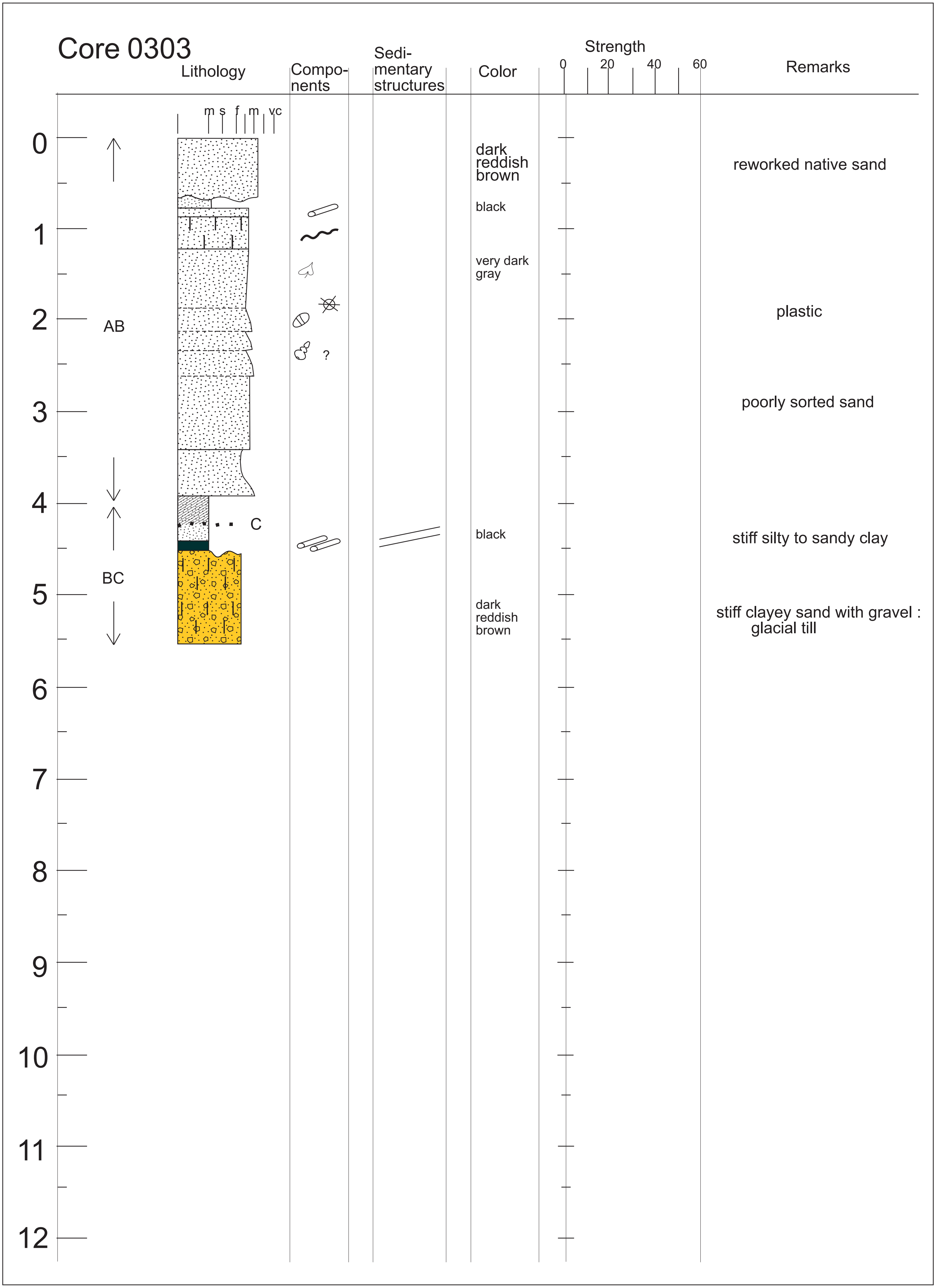


(Source: http://pubs.usgs.gov/of/2006/1195/htmldocs/images/chart.gif)

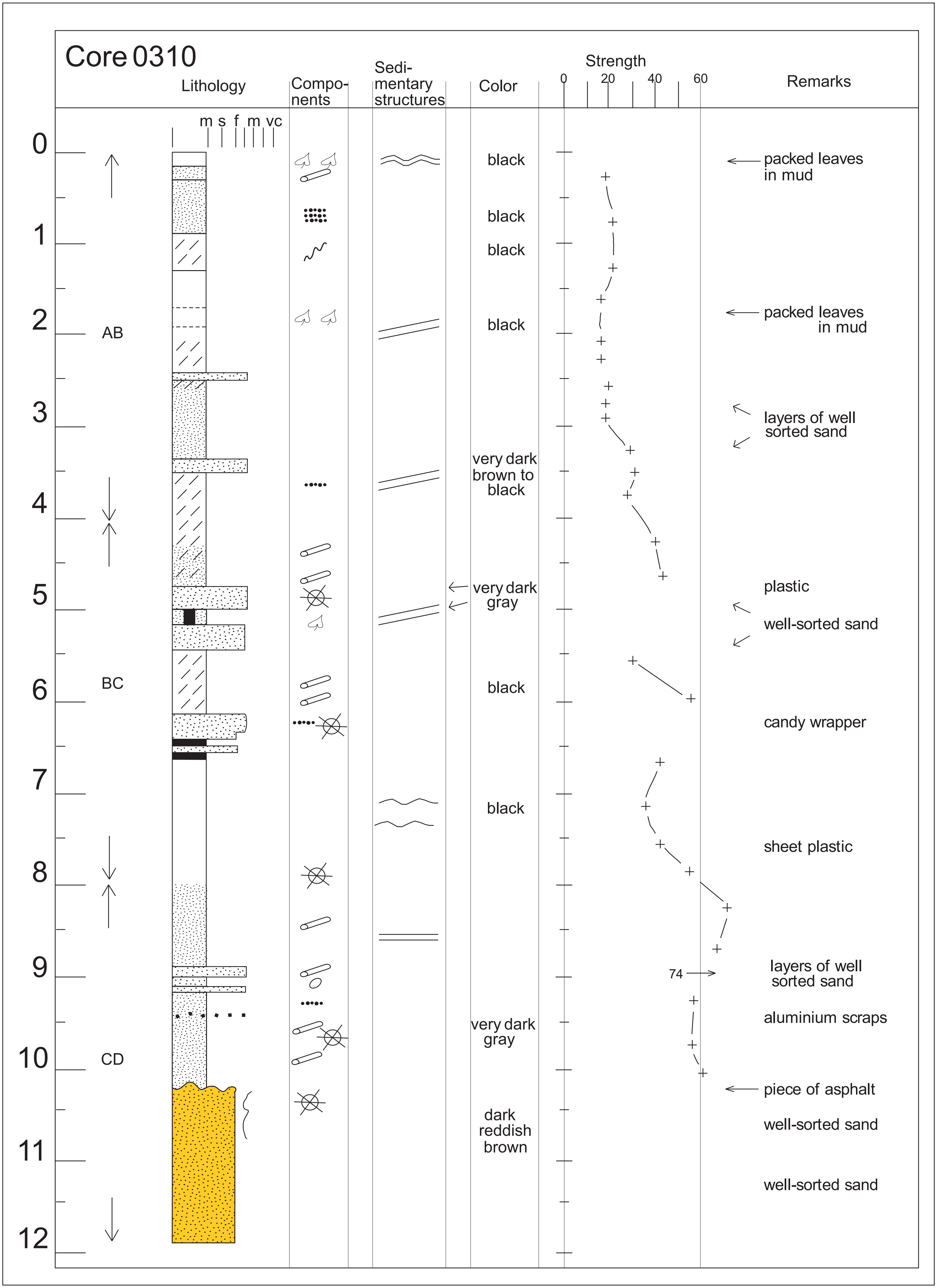
C Appendix 3

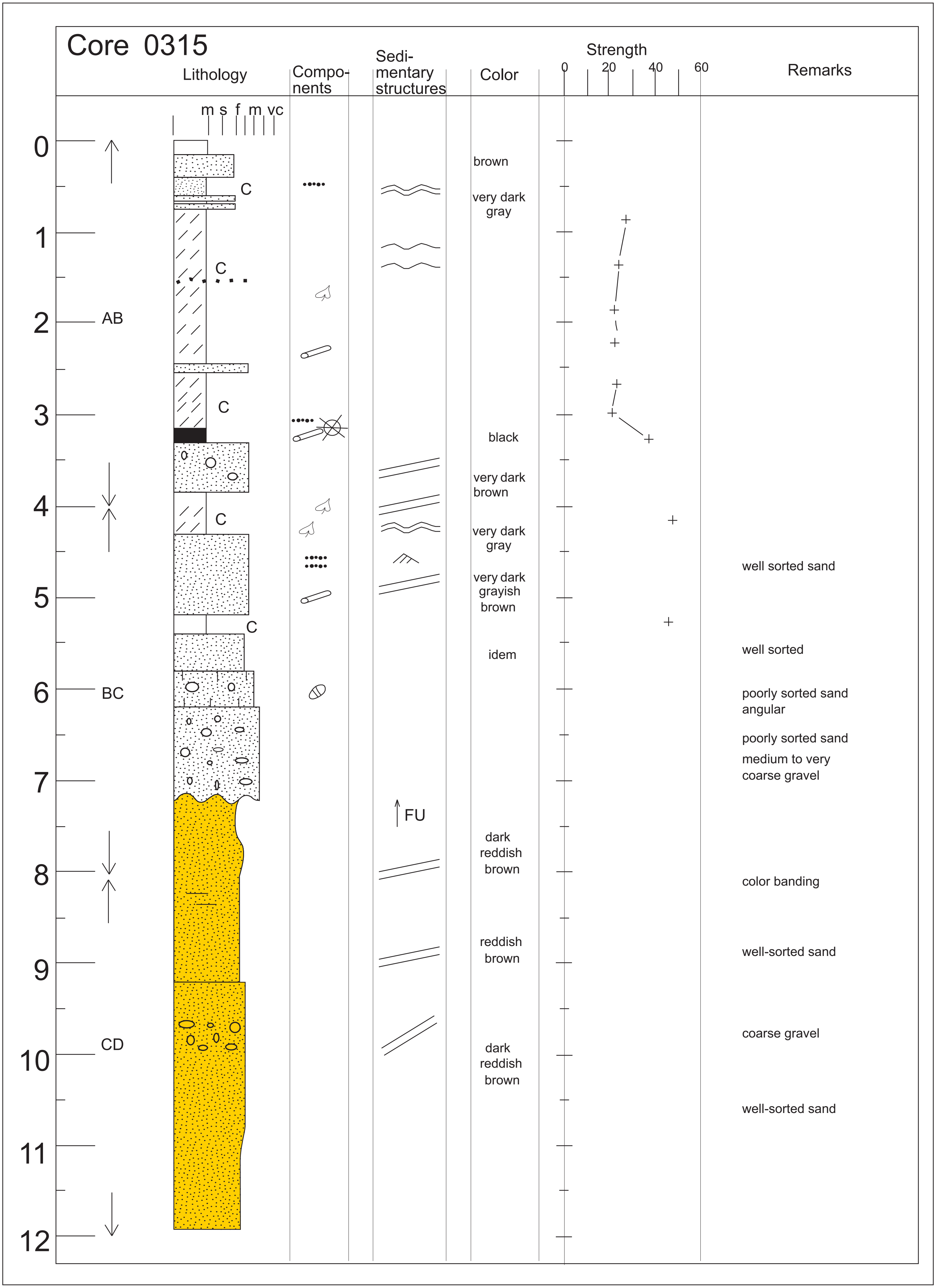
Legend Core Logs



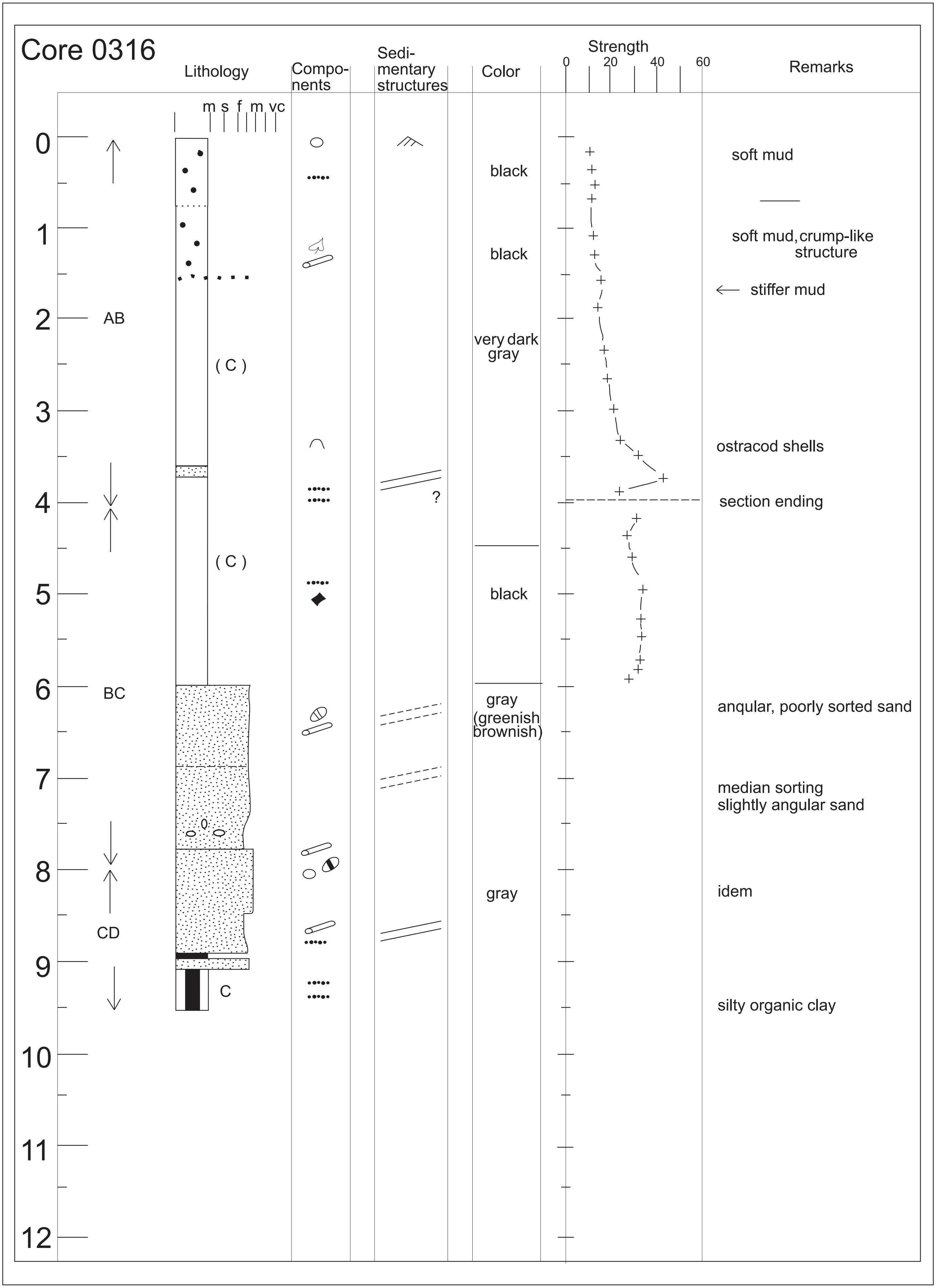


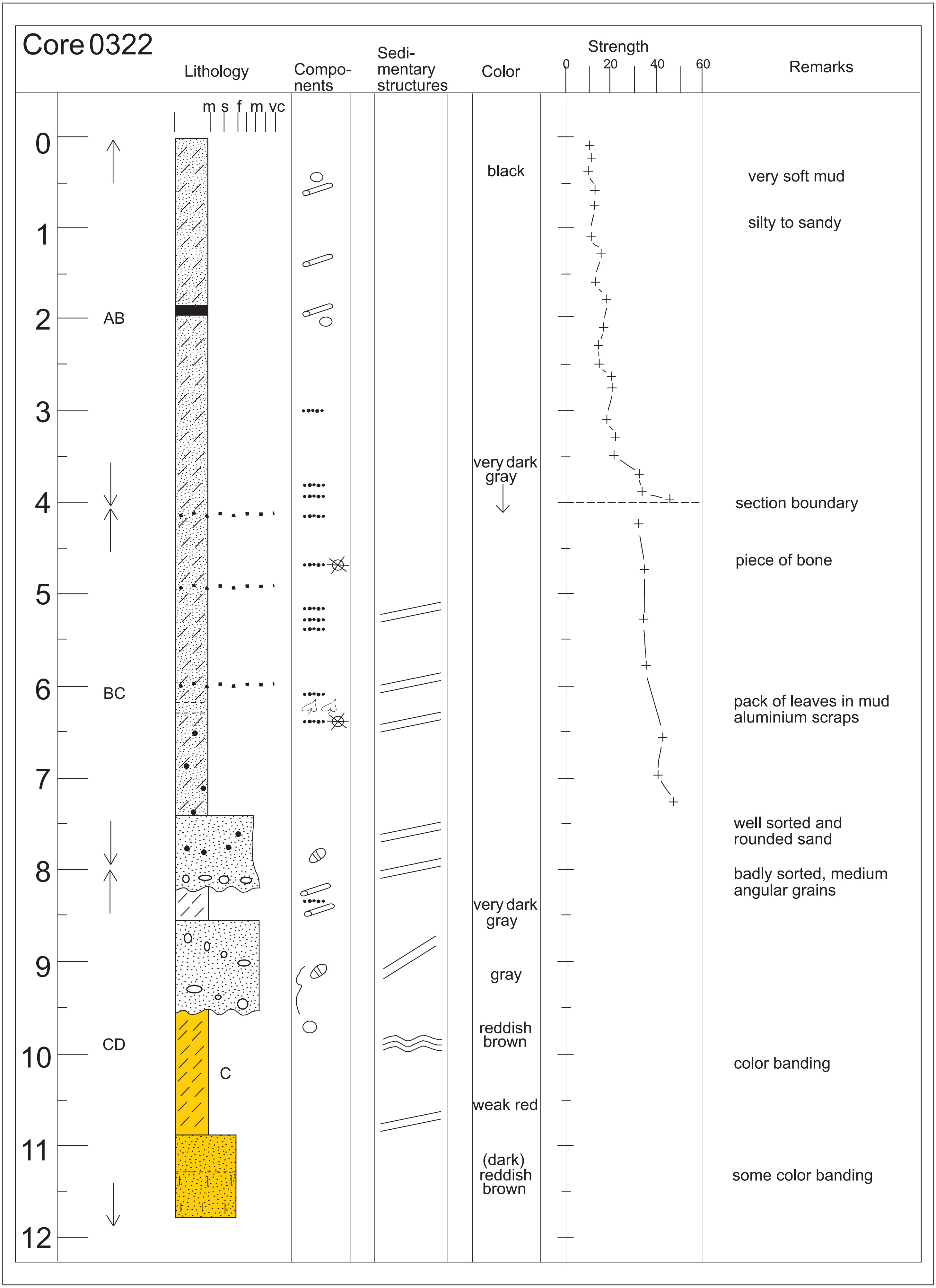
Core 0303
Lithology
m s f m vc
Compo-nents
Sedi-mentary structures
Color
Strength
0 20 40 60
Remarks
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
C
BC
?
dark reddish brown
black
very dark gray
black
dark reddish brown
reworked native sand
plastic
poorly sorted sand
stiff silty to sandy clay
stiff clayey sand with gravel : glacial till


Core 0310
Lithology
m s f m vc
Compo-nents
Sedi-mentary structures
Color
Strength
0 20 40 60
Remarks
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
CD
black
black
black
black
very dark brown to black
very dark gray
black
black
very dark gray
dark reddish brown
packed leaves in mud
packed leaves in mud
layers of well sorted sand
plastic
well-sorted sand
candy wrapper
sheet plastic
74
layers of well sorted sand
aluminium scraps
piece of asphalt
well-sorted sand
well-sorted sand

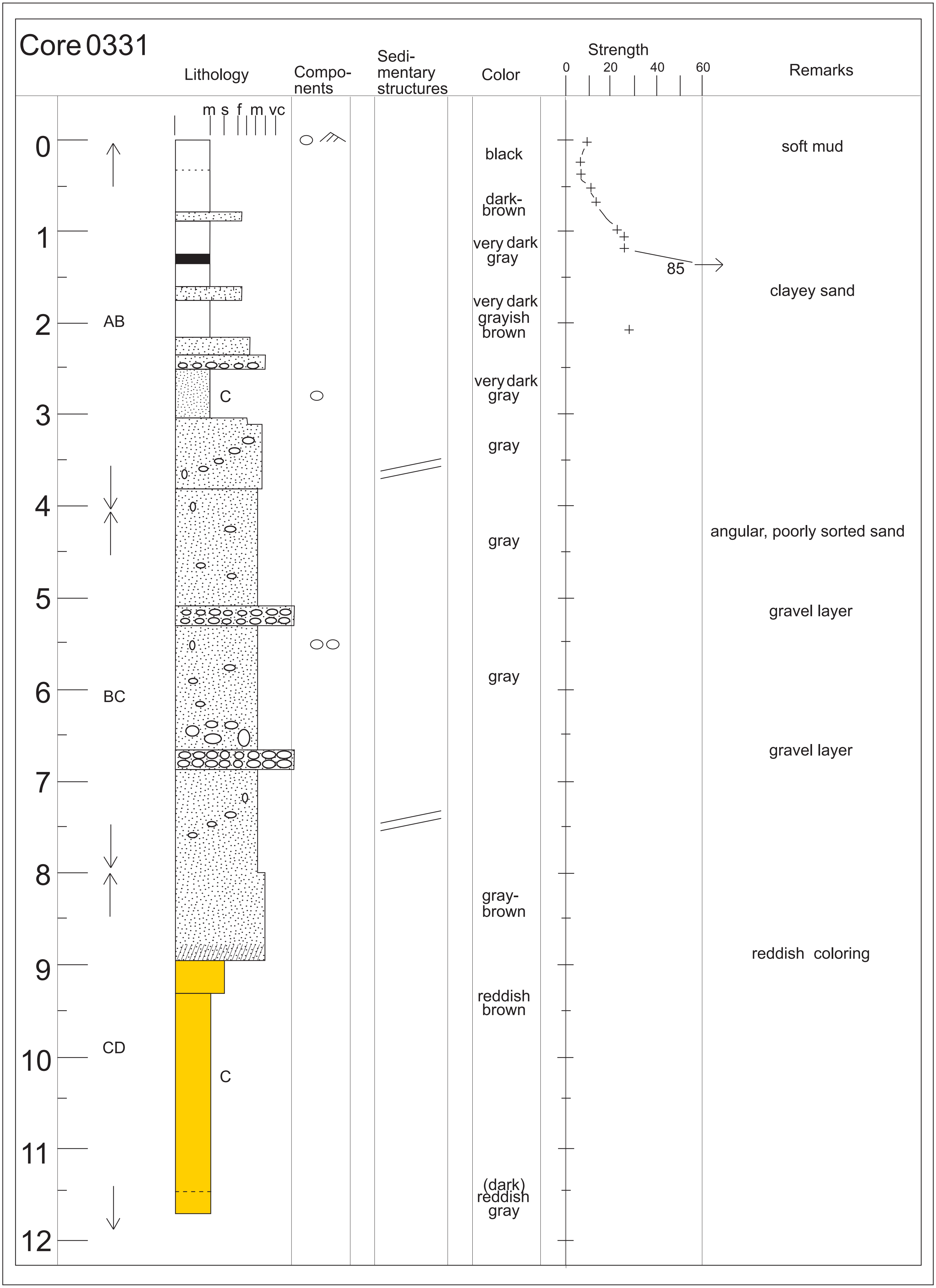


Core 0315
Lithology
m s f m vc
Compo-
nents
Sedi-
mentary
structures
Color
Strength
0
20
40
60
Remarks
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
CD
C
C
C
C
C
FU
brown
very dark
gray
black
very dark
brown
very dark
gray
very dark
grayish
brown
idem
dark
reddish
brown
reddish
brown
dark
reddish
brown
well sorted sand
well sorted
poorly sorted sand
angular
poorly sorted sand
medium to very
coarse gravel
color banding
well-sorted sand
coarse gravel
well-sorted sand

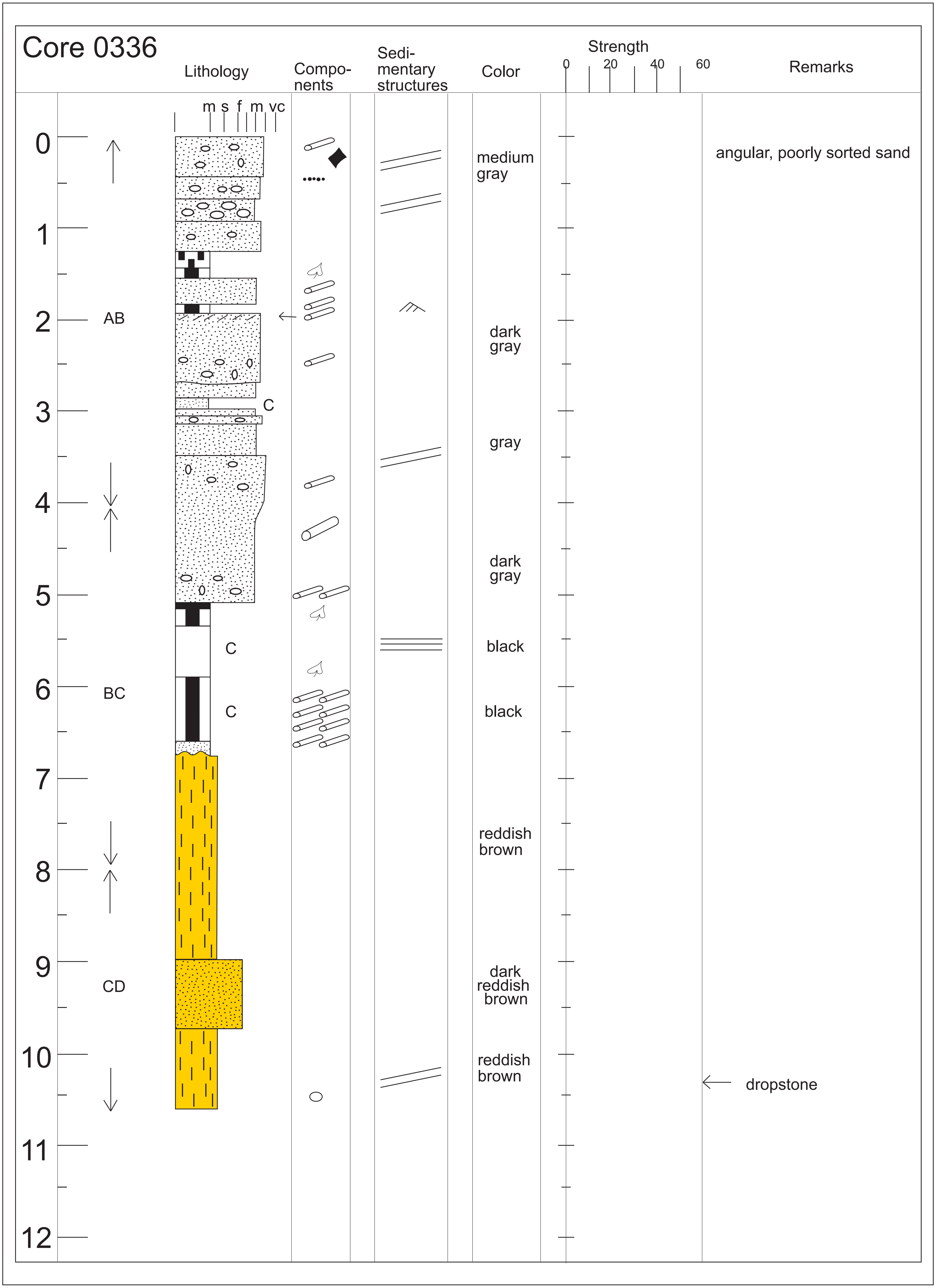

Core 0316
Lithology
Compo-nents
Sedi-mentary structures
Color
Strength
0 20 40 60
Remarks
m s f m vc
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
CD
(C)
(C)
C
?
black
black
very dark gray
black
gray (greenish brownish)
gray
soft mud
soft mud, crump-like structure
stiffer mud
ostracod shells
section ending
anqular, poorly sorted sand
median sorting
slightly angular sand
idem
silty organic clay



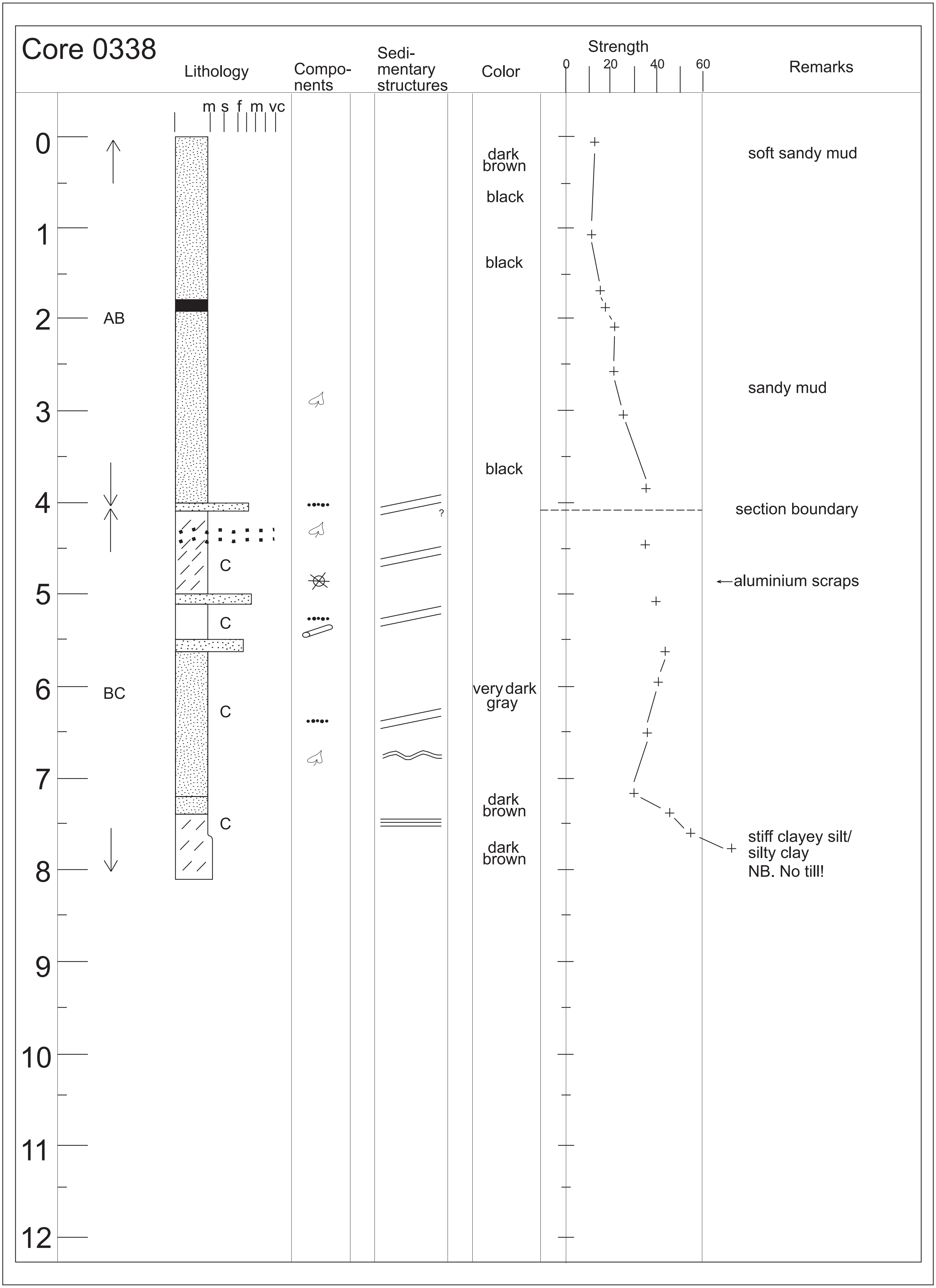
Core 0322
Lithology
m s f m vc
Compo-nents
Sedi-mentary structures
Color
Strength
0 20 40 60
Remarks
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
CD
C
black
very dark gray
very dark gray
gray
reddish brown
weak red
(dark) reddish brown
very soft mud
silty to sandy
section boundary
piece of bone
pack of leaves in mud aluminium scraps
well sorted and rounded sand
badly sorted, medium angular grains
color banding
some color banding

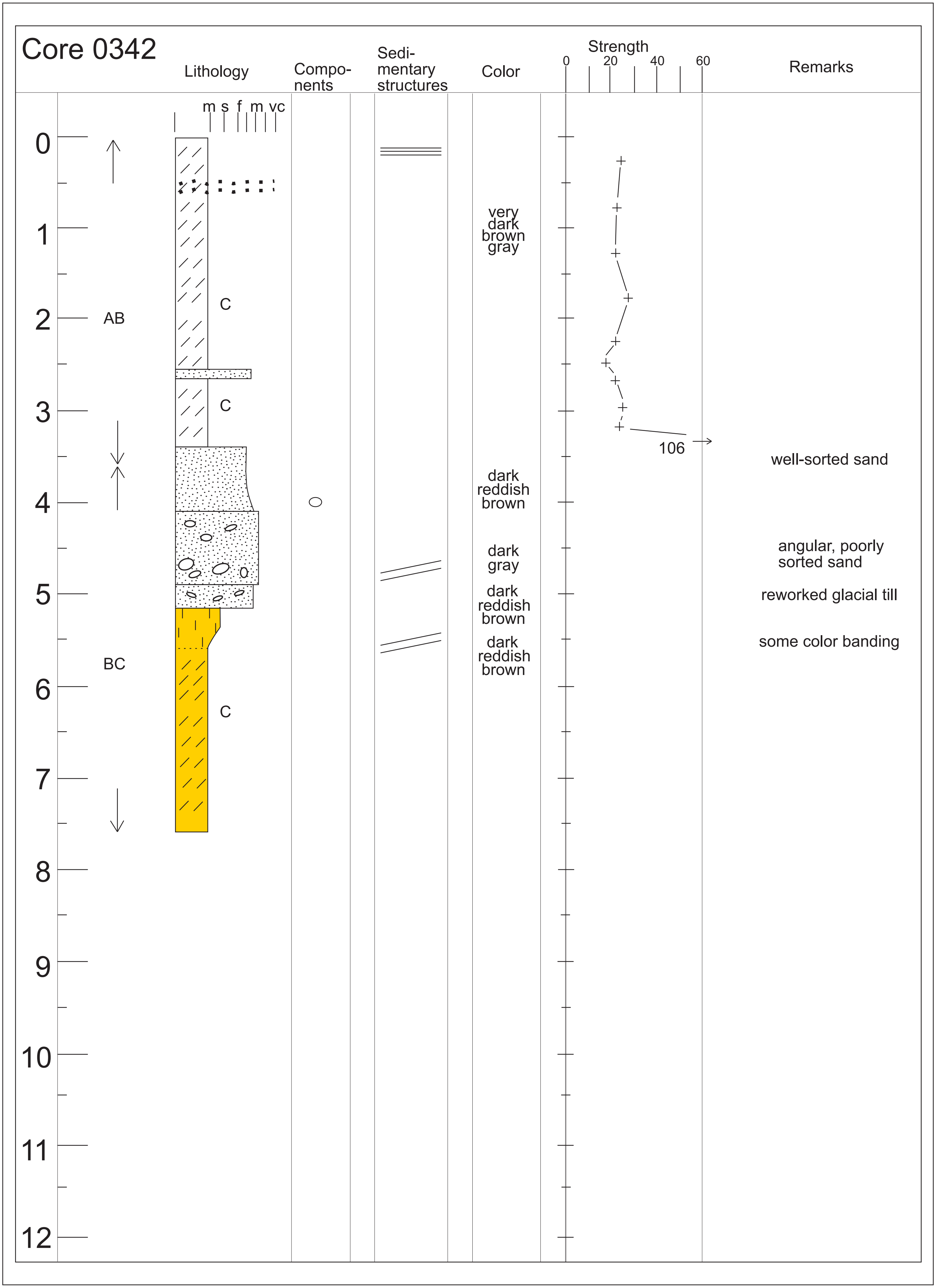


Core 0331
Lithology
Compo-
nents
Sedi-
mentary
structures
Color
Strength
0
20
40
60
Remarks
m s f m vc
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
CD
C
C
85
black
dark-
brown
very dark
gray
very dark
grayish
brown
very dark
gray
gray
gray
gray
gray-
brown
reddish
brown
(dark)
reddish
gray
soft mud
clayey sand
angular, poorly sorted sand
gravel layer
gravel layer
reddish coloring

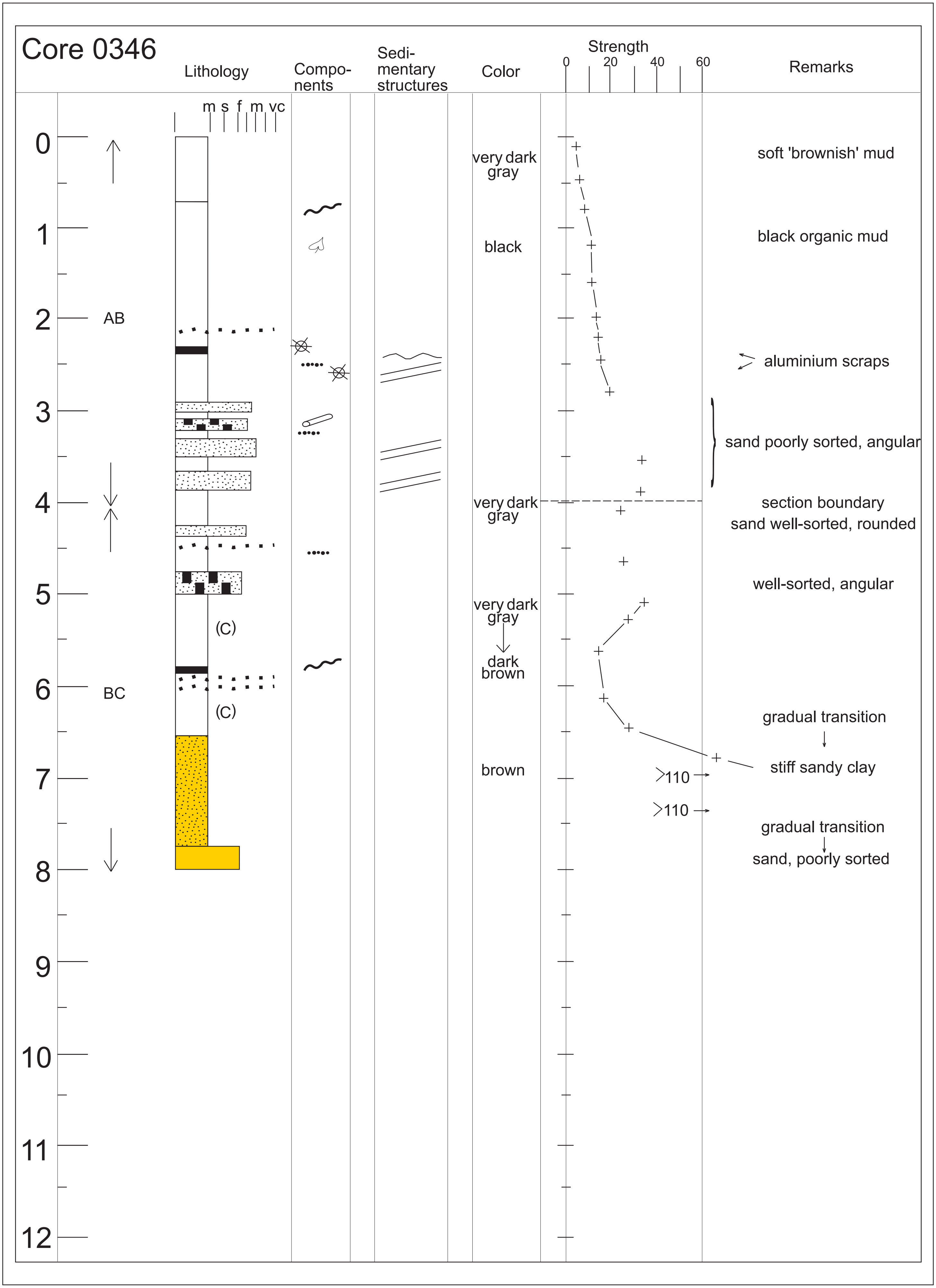


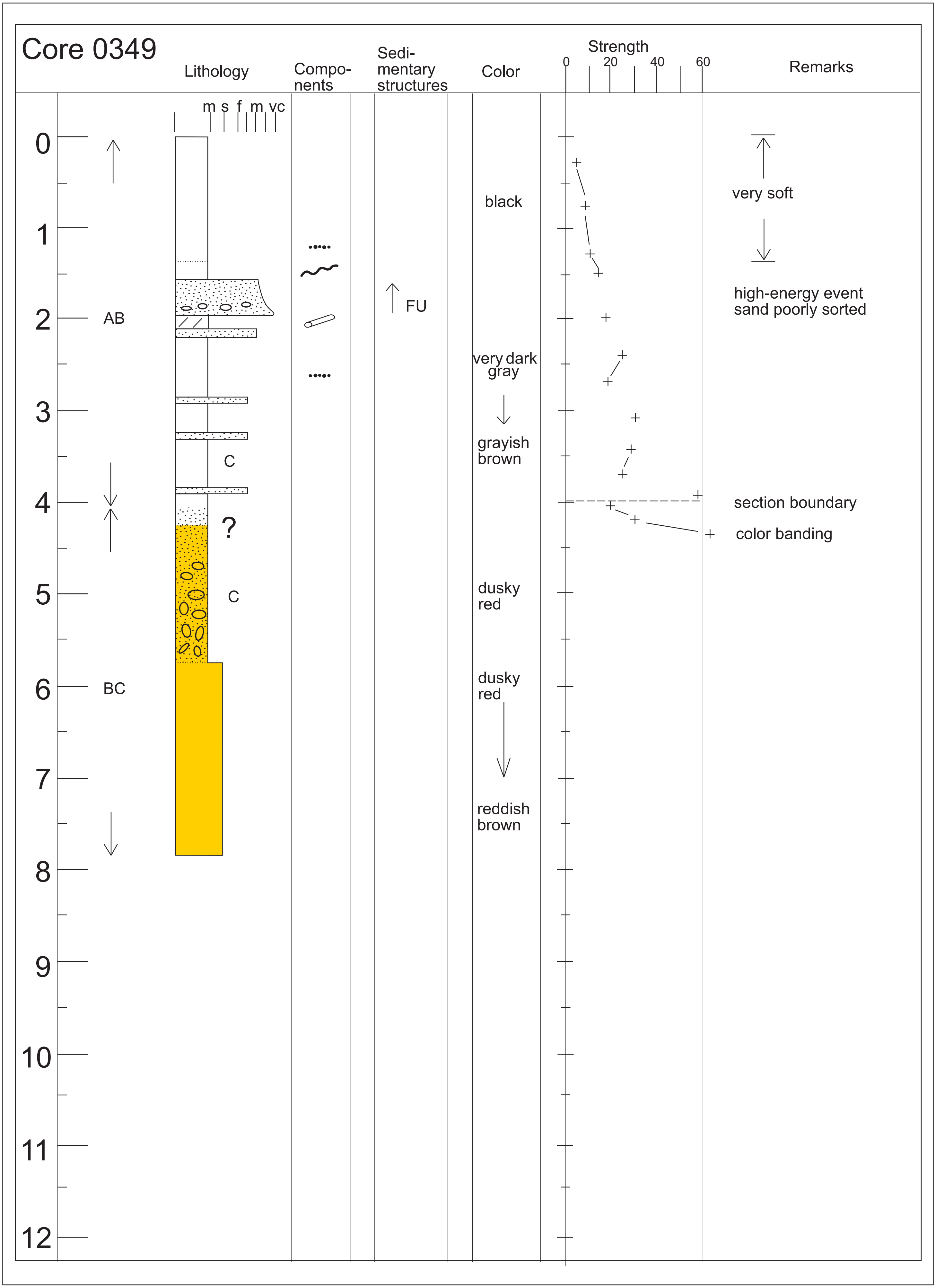
Core 0336
Lithology
Compo-
nents
Sedi-
mentary
structures
Color
Strength
0
20
40
60
Remarks
m s f m vc
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
CD
C
C
C
medium
gray
dark
gray
gray
dark
gray
black
black
reddish
brown
dark
reddish
brown
reddish
brown
angular, poorly sorted sand
dropstone


Core 0338
Lithology
Compo-
nents
Sedi-
mentary
structures
Color
Strength
0
20
40
60
Remarks
m s f m vc
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
C
C
C
C
?
dark
brown
black
black
black
very dark
gray
dark
brown
dark
brown
soft sandy mud
sandy mud
section boundary
aluminium scraps
stiff clayey silt/
silty clay
NB. No till!



Core 0342
Lithology
Compo-
nents
Sedi-
mentary
structures
Color
Strength
0
20
40
60
Remarks
m s f m vc
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
C
C
C
very
dark
brown
gray
dark
reddish
brown
dark
gray
dark
reddish
brown
dark
reddish
brown
106
well-sorted sand
angular, poorly
sorted sand
reworked glacial till
some color banding

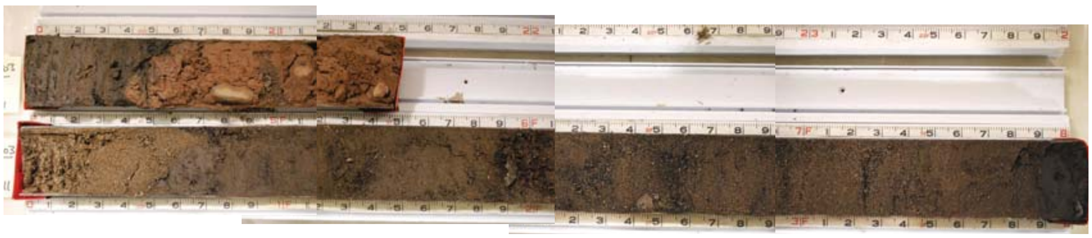

Core 0346
Lithology
Compo-
nents
Sedi-
mentary
structures
Color
Strength
0
20
40
60
Remarks
m s f m vc
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
(C)
(C)
very dark
gray
black
very dark
gray
very dark
gray
dark
brown
brown
>110
>110
soft 'brownish' mud
black organic mud
aluminium scraps
sand poorly sorted, angular
section boundary
sand well-sorted, rounded
well-sorted, angular
gradual transition
stiff sandy clay
gradual transition
sand, poorly sorted



Core 0349
Lithology
m s f m vc
Compo-
nents
Sedi-
mentary
structures
Color
Strength
0 20 40 60
Remarks
0
1
2
3
4
5
6
7
8
9
10
11
12
AB
BC
C
?
C
FU
black
very dark
gray
grayish
brown
dusky
red
dusky
red
reddish
brown
very soft
high-energy event
sand poorly sorted
section boundary
color banding

D Appendix 4

Core 0303



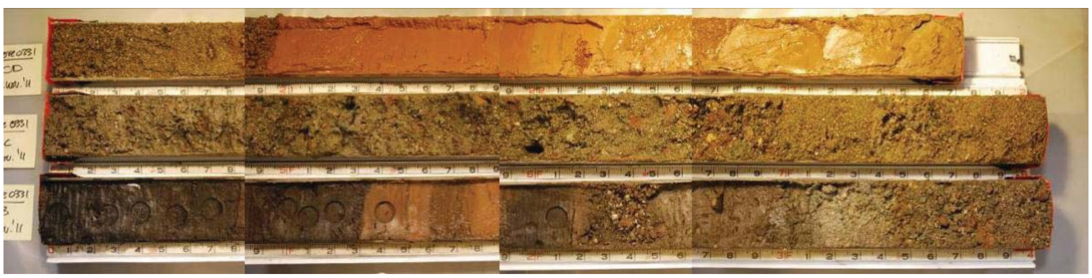
Core 0310

Core 0315

Core 0316

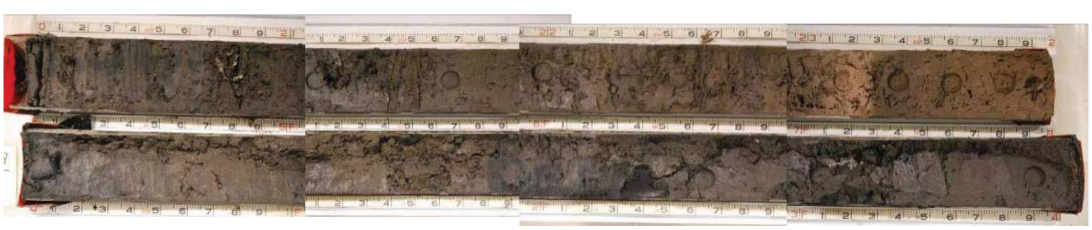
Core 0322

Core 0331



Core 0336

Core 0338



Core 0342

Core 0346

Core 0349